fringe field electrodes **319** and **321**, and storage capacitors **323** and **325**. Storage capacitors **323** and **325** each have a capacitance of about 300 fF (femto-Farads). A lower electrode of fringe field electrode **321** of pixel **303** can be connected, through xVcom **316**, to a charge amplifier **326** in the sense circuitry. Charge amplifier **326** holds this line at a virtual ground such that any charge that gets injected from fringe field electrode **321** shows up as a voltage output of the amplifier. While the feedback element of the amplifier is shown as a capacitor, it may also function as a resistor or a combination of a resistor and capacitor. The feedback can also be, for example, a resistor and capacitor feedback for minimizing die-size of the touch sensing circuitry. FIG. **3** also shows a finger **327** that creates a stray capacitance of approximately 3 fF with a cover glass (not shown), and shows other stray capacitances in the pixels, each of which is approximately 3 fF.

**[0093]** FIG. **4**A shows example signals applied through xVcom **315** to the pixels of the drive region, including pixel **301**, during an LCD phase and during a touch phase. During the LCD phase, xVcom **315** is driven with a square wave signal of 2.5V±2.5V, in order to perform LCD inversion. The LCD phase is 12 ms in duration. In the touch phase, xVcom **315** is driven with 15 to 20 consecutive stimulation phases lasting 200 microseconds each. The stimulation signals in this case are sinusoidal signals of 2.5V±2V each having the same frequency and a relative phase of either 0 degrees or 180 degrees (corresponding to "+" and "−" in FIG. **4**A). The touch phase is 4 ms in duration.

**[0094]** FIG. **5**A shows details of the operation of storage capacitor **323** during the touch phase. In particular, because the capacitance of storage capacitor **323** is much higher than the other capacitances, i.e., stray capacitances shown in FIG. **3**, almost all (approximately 90%) of the AC component of the 2.5V ±2V sinusoidal stimulation signal that is applied at the lower electrode of the storage capacitor is transferred to the upper electrode. Therefore, the upper electrode, which is charged to 4.5 volts DC for the operation of the LCD, sees a sinusoidal signal of 4.5V ±1.9V. These signals are passed to the corresponding left and right comb structures of fringe field electrode **319**. In this way, both comb structures of fringe field electrode **319** can be modulated with a signal having an AC component of approximately ±2V in amplitude (±2V on one, ±1.9V on the other). Thus, fringe field electrode **319**, together with the other fringe field electrodes of pixels in the drive region being similarly driven, can operate as a drive line for capacitive sensing.

**[0095]** It is important to note that at the same time fringe field electrode **319** is configured to operate as a drive element for the touch sensing system, the fringe field electrode continues to operate as a part of the LCD display system. As shown in FIG. **5**A, while the voltages of the comb structures of fringe field electrode are each modulated at approximately ±2V, the relative voltage between the comb structures remains approximately constant at 2V ±0.1V. This relative voltage is the voltage that is seen by the liquid crystal of the pixel for the LCD operation. The 0.1V AC variance in the relative voltage during the touch phase should have an acceptably low affect on the LCD display, particularly since the AC variance would typically have a frequency that is higher than the response time for the liquid crystal. For example, the stimulation signal frequency, and hence the frequency of the AC variance, would typically be more than 100 kHz. However, the response time for liquid crystal is typically less than 100 Hz. Therefore, the fringe field electrode's function as a drive element in the touch system should not interfere with the fringe field electrode's LCD function.

**[0096]** Referring now to FIGS. **3**, **4**B, and **5**B, an example operation of the sense region will now be described. FIG. **4**B shows signals applied through xVcom **316** to the pixels of the sense region, including pixel **303**, during the LCD and touch phases described above. As with the drive region, xVcom **316** is driven with a square wave signal of 2.5V±2.5V in order to perform LCD inversion during the LCD phase. During the touch phase, xVcom **316** is connected to amplifier **326**, which holds the voltage at or near a virtual ground of 2.5V. Consequently, fringe field electrode **321** is also held at 2.5V. As shown in FIG. **3**, fringing electrical fields propagate from fringe field electrode **319** to fringe field electrode **321**. As described above, the fringing electric fields are modulated at approximately ±2V by the drive region. When these fields are received by the top electrode of fringing field electrode **321**, most of the signal gets transferred to the lower electrode, because pixel **303** has the same or similar stray capacitances and storage capacitance as pixel **301**. Because xVcom **316** is connected to charge amplifier **326**, and is being held at virtual ground, any charge that gets injected will show up as an output voltage of the charge amplifier. This output voltage provides the touch sense information for the touch sensing system. For example, when finger **327** gets close to the fringing fields, it captures some fields and grounds them, which causes a disturbance in the fields. This disturbance can be detected by the touch system as a disturbance in the output voltage of charge amplifier **326**. FIG. **5**B shows that approximately 90% of a received fringing field at pixel **302** which impinges onto the electrode half of the capacitor which is also connected to the drain of the TFT **325** will be transferred to charge amplifier **326**. 100% of the charge that impinges onto the electrode half of the capacitor which is connected directly to XVCOM **316** will be transferred to charge amplifier **326**. The ratio of charge impinging onto each electrode will depend on the LCD design. For non-IPS, near 100% of the finger affected charge will impinge on the VCOM electrode because the patterned CF plate is nearest the finger. For IPS type display the ratio will be closer to half and half because each part of the electrode has approximately equal area (or ¼ vs. ¾) facing the finger. For some sub-types of IPS displays, the fringing electrodes are not coplanar, and the majority of the upward facing area is devoted to the VCOM electrode.

**[0097]** The example driving and sensing operations of FIGS. **3**, **4**A-B, and **5**A-B are described using single pixels for the sake of clarity. Some example layouts and operations of drive regions and sense regions according to embodiments of the invention will now be described with reference to FIGS. **6**A-C, **7**, **8**A-C, **9**A-C, and **10**.

**[0098]** FIG. **6**A illustrates a partial view of an example touch screen **600** having regions of pixels with dual-function capacitive elements that operate as LCD elements and as touch sensors according to embodiments of the invention. In the example of FIG. **6**A, touch screen **600** having eight columns (labeled a through h) and six rows (labeled **1** through **6**) is shown, although it should be understood that any number of columns and rows can be employed. Columns a through h can be formed from column-shaped regions, although in the example of FIG. **6**A, one side of each column includes staggered edges and notches designed to create separate sections in each column. Each of rows **1** through **6** can be formed from a plurality of distinct patches or pads within the regions, each